$$Z^0 \rightarrow \tau\overline{\tau} \rightarrow \mu\nu_\mu\nu_\tau\tau_{had}\nu_\tau$$

Tau leptons are produced by the rather well known processes of W/Z^0vector boson production with a decay of the electroweak boson into a $\tau\overline{\tau}$ pair resp. $\tau\overline{\nu}_\tau$pair.
In contrast to the lighter leptons, the tau has a short lifetime and thus only its decays products are measured by the detector. The final states with the largest branching fractions are given in table on the left of table 4.1, the final states for the $Z^0\rightarrow\tau\overline{\tau}$ process are given on the right side of the same table.

τ decay channel	BF in %
electron	17.8
μ	17.4
1 $\pi^{\pm}$	11.1
1 $\pi^{\pm}$+ n π^{+}	36.9
3 $\pi^{\pm}$	10.
3 $\pi^{\pm}$+ n π^{+}	5.2

$Z^0\rightarrow\tau\overline{\tau}$ decay channel	BF in %
ee	3.2
$\mu\mu$	3.0
eμ	6.2
had e	23.0
had μ	22.5
had had	42

Table 4.1: The branching fraction of most common τdecays (left) and the final state signatures of Z production with following decay of the Z into a τpair.

For the data=taking period used for Moriond 2003 analyses, the track trigger was not availible.
Thus the only decay modes with a lepton in the final state passed any trigger requirement.
Here, we'll concentrate on the muon-hadronic channel.

The starting point is an (isolated) muon, so the first section is concerned with the determination of all applicable muon efficiencies.

The second part will concentrate on the definition of the candidate and control sample.
More specifically this deal with muon isolation and rejection of di-muon events from cosmics or direct Z decays into muons

The third section examines the candidate sample to extract Z candidates and concludes with the reconstruction of the Z mass.

(so far, work concentrates on the determination of muon efficiencies and will hopefully cover more in the near future)

Section 1) Muon efficiencies:

fall into mainly three parts:
trigger, reconstruction and track matching.

- ϵ(Trigger): the fraction of muons passing the requirements of the trigger at all three stages
- ϵ(reconstruction): the fraction of muons being reconstructed in the local muon system with sufficient quality
- ϵ(track matching): the fraction of muon with a central matched track

All these efficiencies are not independent, for the determination of the total efficiency the equation $\epsilon(A, B) = \epsilon(A|B) \times \epsilon(B)$ is used which says that the efficiency for the requirement A and B is the efficiency for requirement B times the efficiency for A once B has been required. The efficiency can be written as:

$$\begin{aligned} \epsilon = {} & \epsilon(L2|L1, match, reco, geom, pT) \\ & \times\epsilon(L1|match, reco, geom, pT) \\ & \times\epsilon(match|reco, geom, pT) \\ & \times\epsilon(reco|geom, pT) \\ & \times\epsilon(geom, pT) \end{aligned} \tag{4.1}$$

Resulting efficiencies:

Requirement	Efficiency
within fiducial region	0.690 ± 0.005
pT above 6 GeV	0.448 ± 0.027
pT above 15 GeV	0.241 ± 0.027
L1 trigger	0.955 ± 0.013
L2 trigger	$0.85 \pm$
reconstruction	$0.85\pm$
track match	$0.8 \pm$
timing	0.989 ± 0.0024

Muon Acceptance:

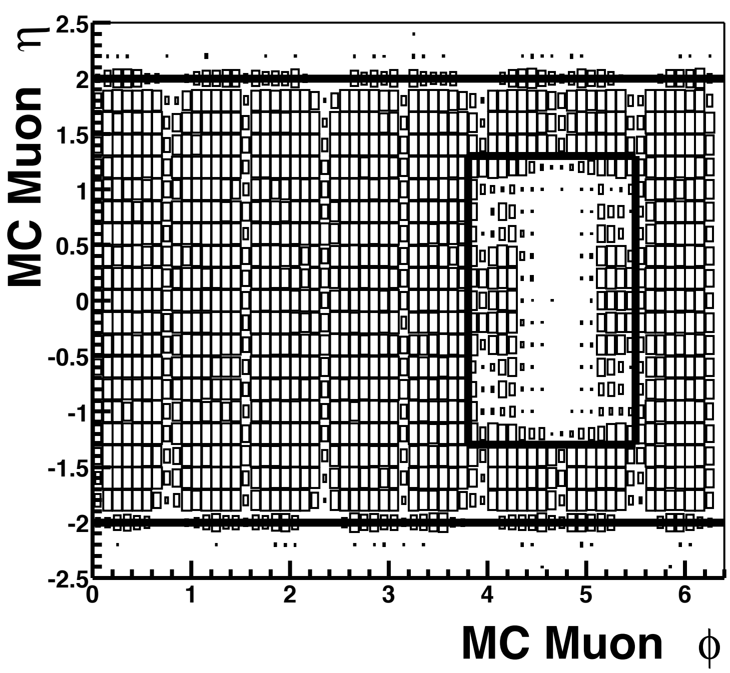
The fiducial region is defined using a Z $\mu\mu$ MC sample trying to keep a region where the detector show a flat reconstruction efficiency.
The cuts used are:

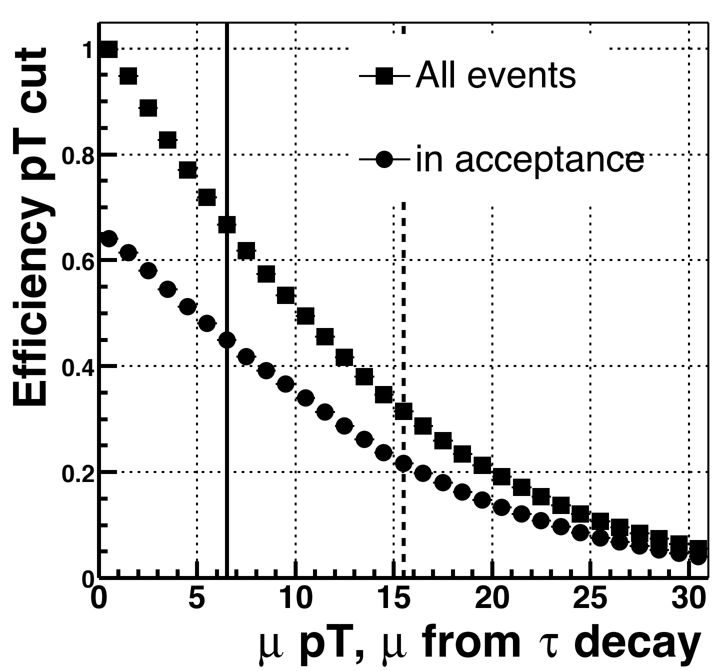
$|\eta| < 2$

$|\eta| < 1.3$ and $3.8 < \phi < 5.35$.

The efficiency of this acceptance cut in combination with the requirements on the transverse momentum of the muon are determined using generator level MC events where pT is smeared to have the same resolution on the Z peak as observed in data.

Details about the smearing method and the determination of the systemativ error on the acceptance*pT cut can be found here and in the W $\mu\nu$ cross section note.





Muon reconstruction efficiency:

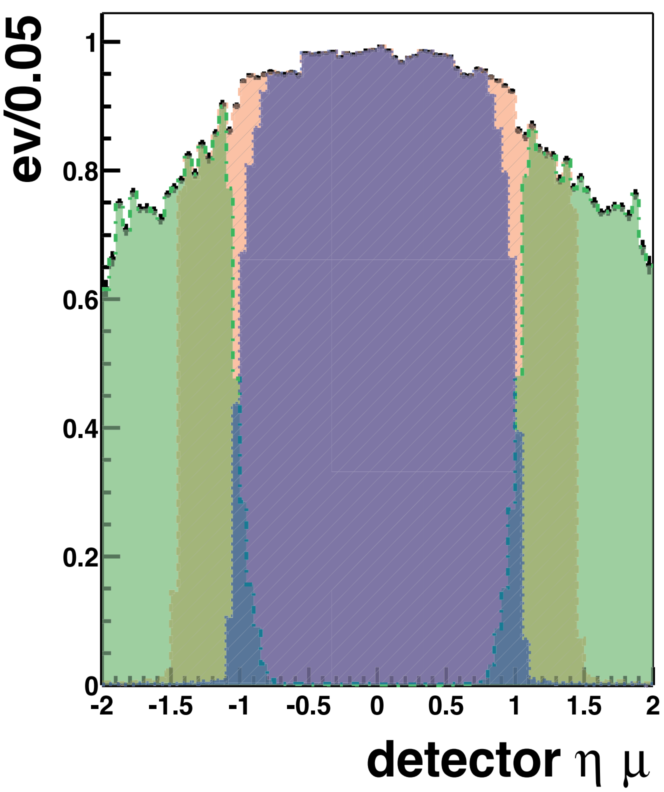
The efficiency ot reconstruct a muon of medium quality in the local muon system is determined using Z and J/psi events. These evnest are required to have fired a single muon trigger with a L2 requirement. One of the two legs of that di-muon object is required to have a medium local muon track and a matched central track. This muon has to be matched to the L2 trigger muon. This leave an unbiased second muon that will be called “test” muon.
The test muon has to have a central track and the invariant mass of the two central tracks is used to “tag” the test muon. The invariant mass peaks of the Z and the J/psi are fitted and the fraction of events with rec onstructed local muons is extracted.

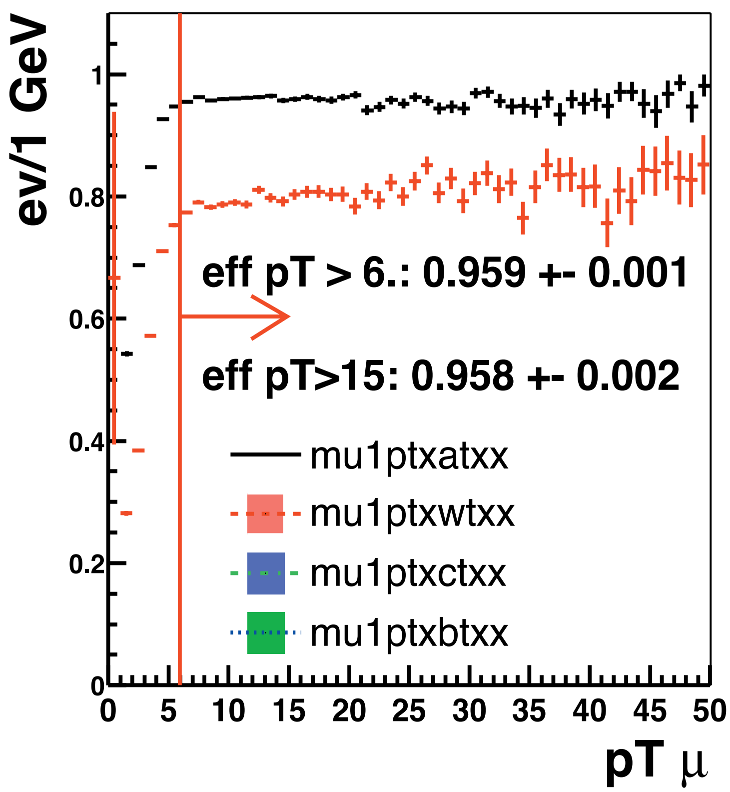
Muon Tracking*matching efficiency:

The sample used for this study consists of eventss with two offline medium quality muons. The events have to pass at least one trigger without a L2 track requirement to have an unbiased estimate of the tracking efficiency before trigger.
The momneta measure in the muon system is used to calculate the invariant amss ot the two muons and the J/psi and Z peaks are fitted for sample of evnts with 2, 1 or 0 matched central tracks. The efficiency is calculated using the formula:
2*N2+N1/2*(N2+N1+N0)

Muon Trigger efficiency at L1:

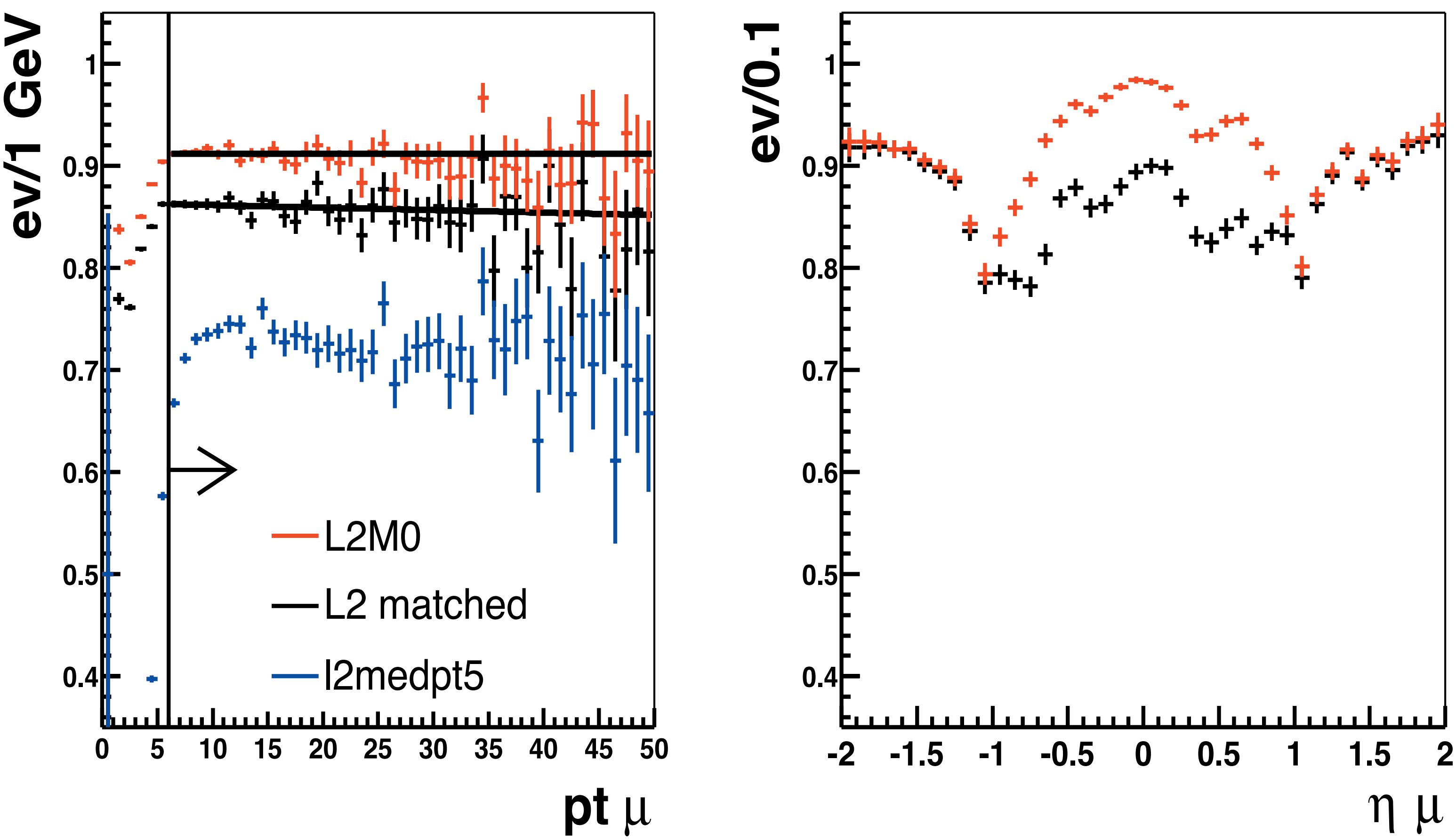
The muon trigger efficiency at L1 is obtained using events triggered with any calorimeter term which have a reconstructed muon. This muon is required to be of medium quality and to have a matched central track. It has to pass the timing cuts and to further reject cosmics, the events with a second muon ($\Delta R > 0.5$) are disregarded. Additionally this rejects events with more than one actual muon which could lead to an overestimate of the trigger efficiency.





Muon Trigger efficiency at L2:

The efficiency of a L2 (medium) muon is obtained using the same data sample as for the L1 study. Again exactly one offline muon of medium quality with a matched track is required and the event has to pass the L1 condition. The offline muon is matched to a global L2 muon in an 0.5 cone.



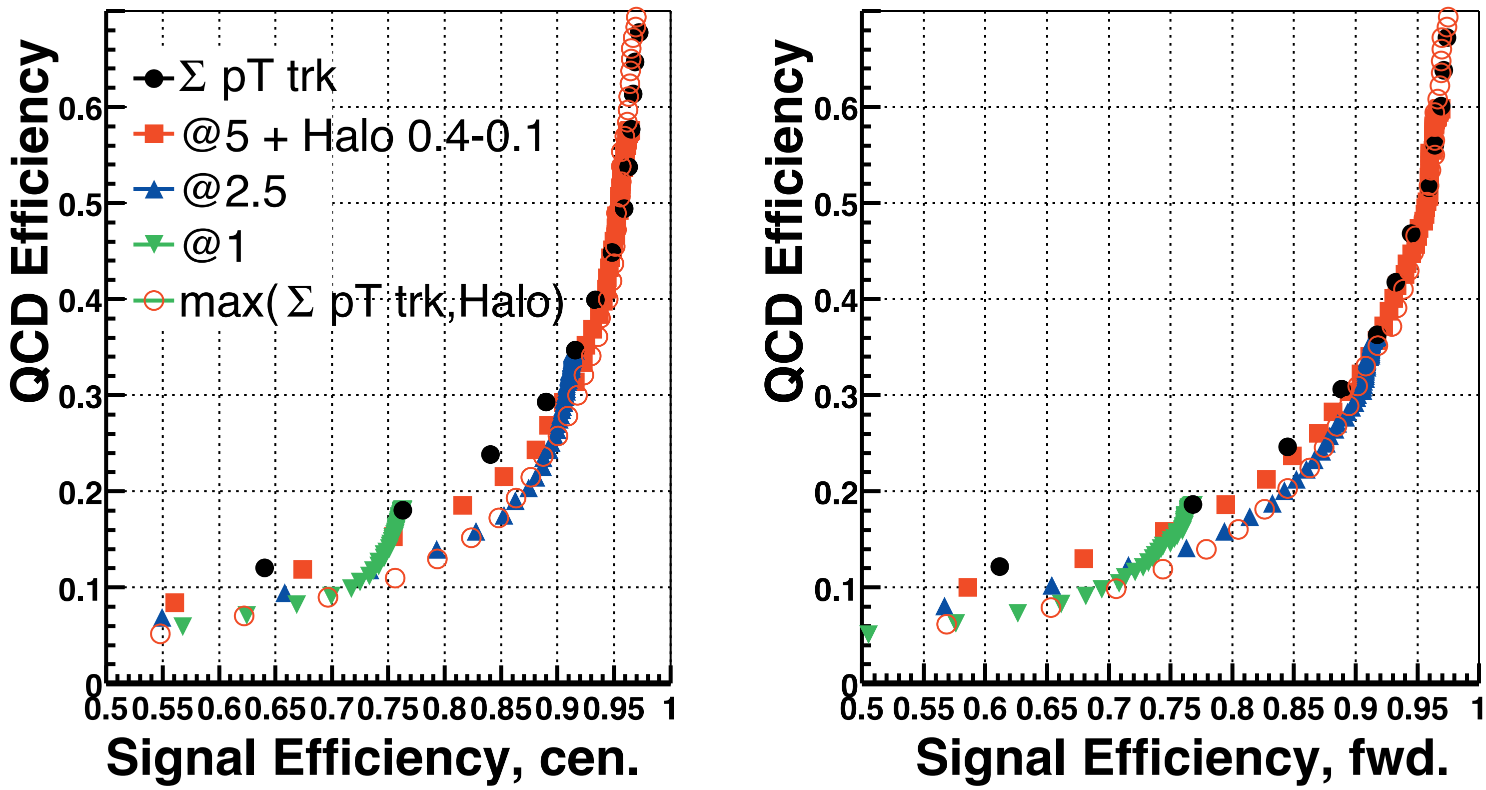
The difference of the efficiencies obtained using the global L2 muons and using the L2 bits can be explained by the angular resolutions of the L2 muons (see detailed plots).

Muon Timing efficiency:

The efficiency of the timing cut for cosmic rejection are determined using events with two reconstructed muons with matched tracks. These events are suppsed to pass a L1 dimuon trigger to emulate evnets where the only muon in the events is required to pass the L1 trigger.
The invariant mass of the two global muon tracks is fitted in the regions of the Z/ J/psi and Upsilon peak for events with 2,1 and 0 muon passing the timing requirement. The same counting methis as for the tracking efficiency is used and the difference of that central value for the three peaks for two different background fits is used to estimate the systematic uncertainty.

Muon Isolation:

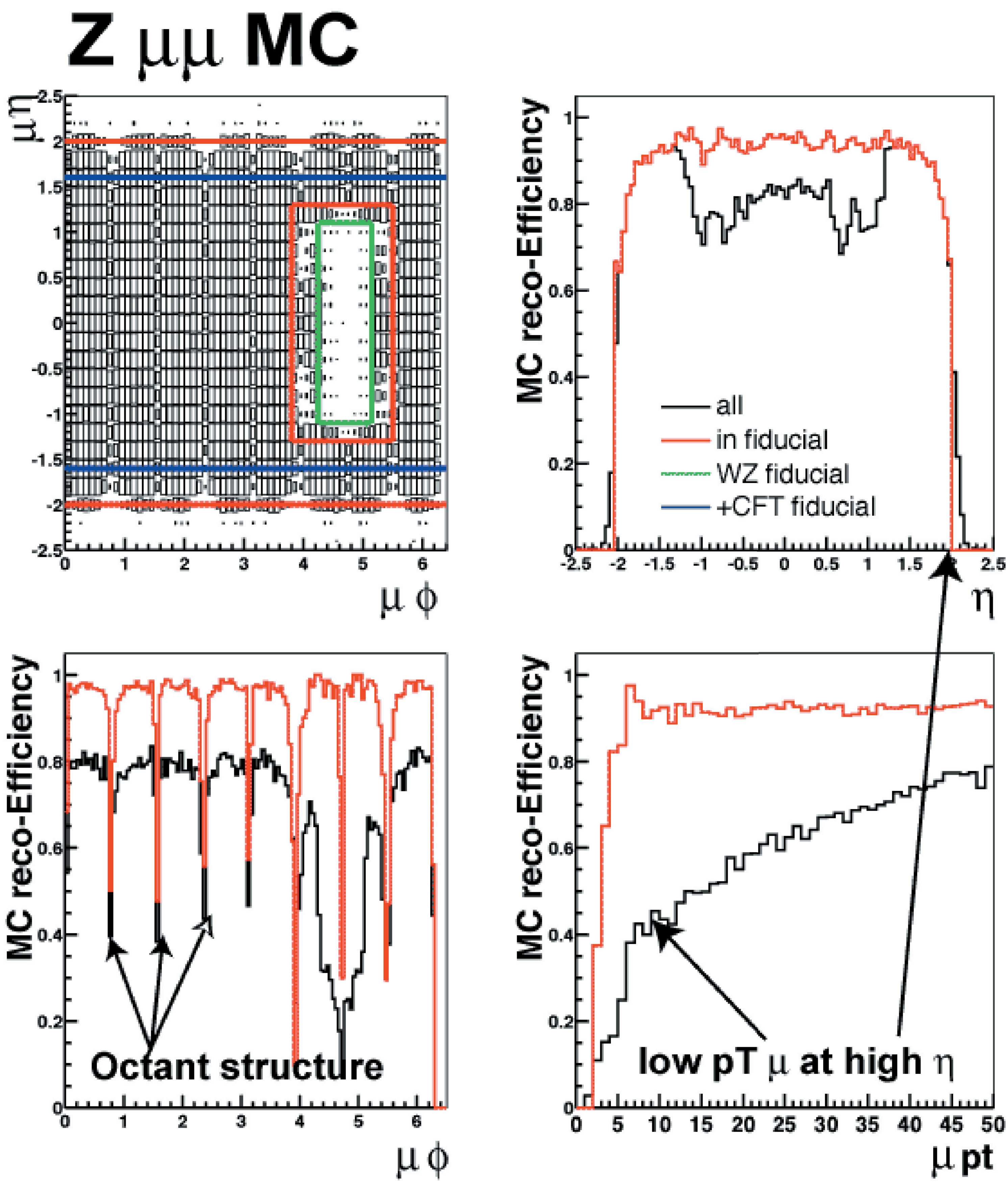
The muon procued by the decay of electroweak bosons (or indrectly through the tau) are isolated in contrast to muons produced in QCD events, e.g. in b or c quark decays. Naively, the isolation caould be definde as distance to a reconstructed jet. As it turns out, the turn-on curves for jet-reconstruction can fail to find low energetic jets, which are then classified as isolated and due to energy fluctuations, the energy deposited by a muon can lead to a jet, which results in inefficiencies of this definition. Thus better variables describing the muon isolation have been studied and reated according to rejection power for a set signal efficiency. There are two sets of variables: one is using the reconstructed tracks in a cone around the muon (excluding the track matched to it), either counting tracks above a transverse momentum threshold or summing their pT.
A similar method can be applied to the energes measured in the calorimeter. The energy deposited by the muon should be excluded so that a hollow cone with an inner and outer radiis is used, both of which can be optimized.
To extract both efficiency and rejection from data, two sample have been used: a sample of selected di-muon events, where both muons are reconstructed locally and have track matched and an invariant mass compatible with the Z mass which provides the “isolated” muons. As background, events with low Missing transverse momentum as expected in QCD events have been selected. Events with second mons are rejection to reduced “signal” contamination.
This study is based on the work described in D0note xxxx.



A number of additional figures can be found later.

The background rejection for a given efficiency is different for central and forward muons and as the jets producing “background” muon get getting more energetic as the muon does, the rejection power is increasing the the pT of the muon.

Muon Acceptance*pT details:



- sytematics for the acceptance from W $\mu\nu$ cross section note

- using η_{phys} instead of η_{det} leads to a 1% difference: $\epsilon_{accept} = 64.08 \pm 0.45$;
- using $|\eta_{det}| < 1.7$ instead of $|\eta_{det}| < 1.6$ leads to $\epsilon_{accept} = 67.10 \pm 0.45$;
- moving h_{CFT} by ± 5 cm leads to a 0.3% effect;
- moving $h_{A\ layer}$ by ± 50 cm leads to a 0.2% effect;
- moving the center of the detector along the beam axis by ± 5 cm leads to a 0.2% effect.

Finally, we find a geometrical acceptance of:

$$\epsilon_{accept} = 63.08 \pm 0.45(stat) \pm 0.25(sys)\%$$

- smear the generated MC pT to have same Z mu mu resolution in data + MC, again from

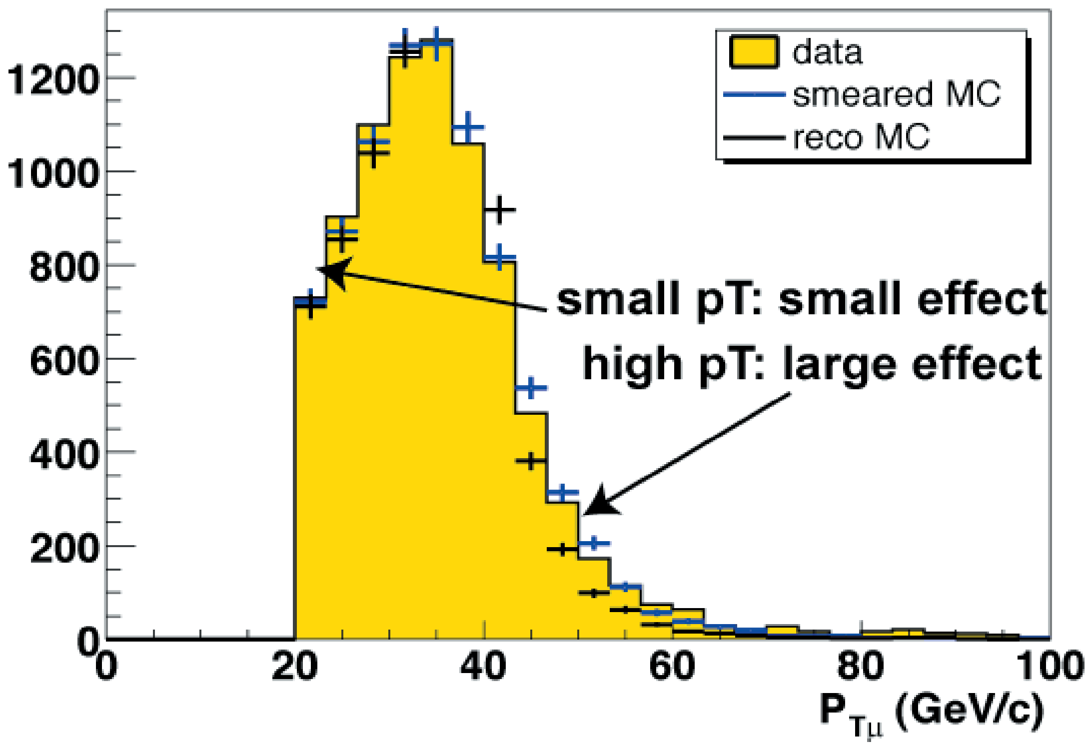
- method 1: $\frac{1}{P_{t\ reco}} \rightarrow \frac{1}{P_{t\ reco}}(1 + fG)$ where f is the smearing factor and G a gaussian distribution;
- method 2: $\frac{1}{P_{t\ reco}} \rightarrow \frac{1}{P_{t\ reco}} + f(\frac{1}{P_{t\ reco}} - \frac{1}{P_{t\ gen}})$ where $P_{t\ reco}$ (respectively $P_{t\ gen}$) is the reconstructed (resp. generated) transverse momentum and f the smearing factor;
- method 3: $\frac{1}{P_{gen}} \rightarrow \frac{1}{P_{gen}}(1 + G\sqrt{A^2 P_t^2 + \frac{B^2}{sin\theta}})$ where θ is the usual polar angle, G a gaussian distribution, B the multiple scattering term taken to be $B = 0.014584$ and A the resolution term to be adjusted: $A = 0.00162 * f$.

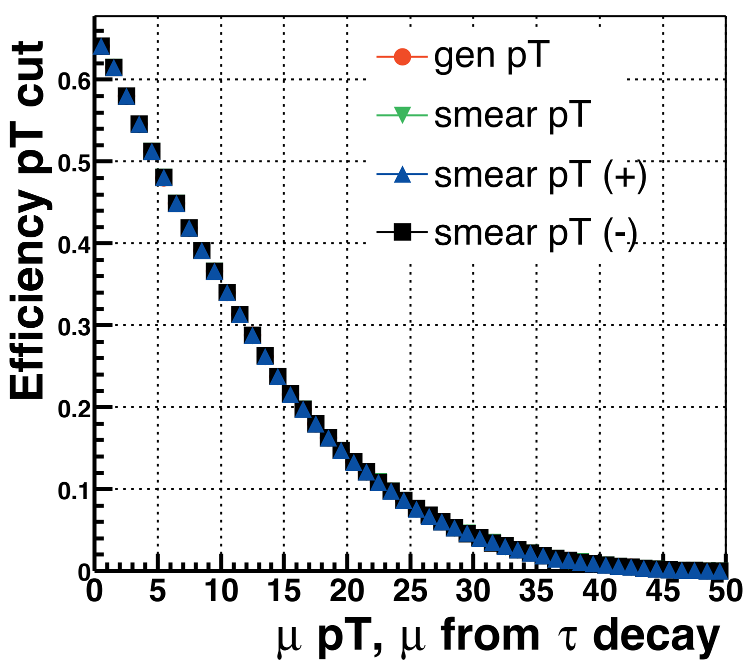
For the 3 methods, we obtain:

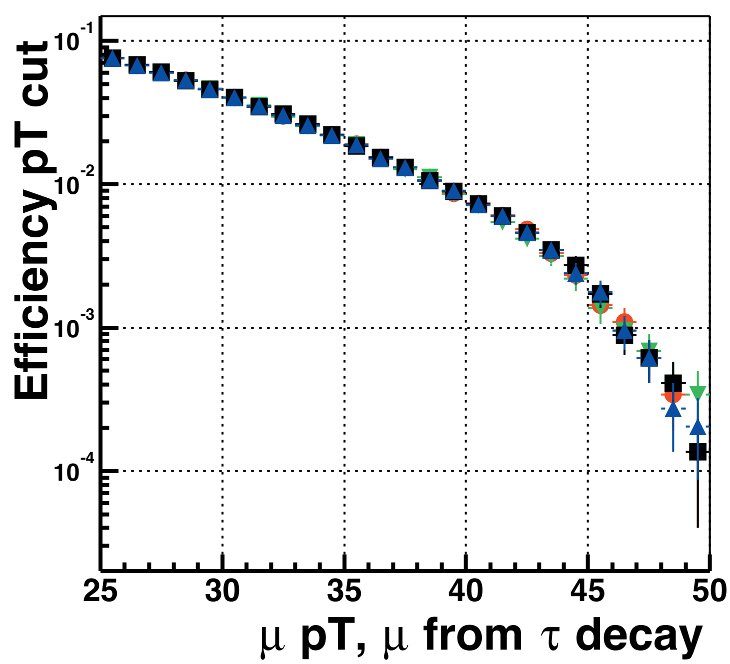
- method 1: $f = 0.12 \pm 0.01$;
- method 2: $f = 1.46 \pm 0.14$;
- method 3: $f = 2.20 \pm 0.17$.

- use Ansatz (3) to smear the generated muon momenta in 41000 Z tautau MC events.

This show the pT of muons from W bosons compared to the (non-)smeared MC distribution (stolen from the W $\mu\nu$ cross section note)



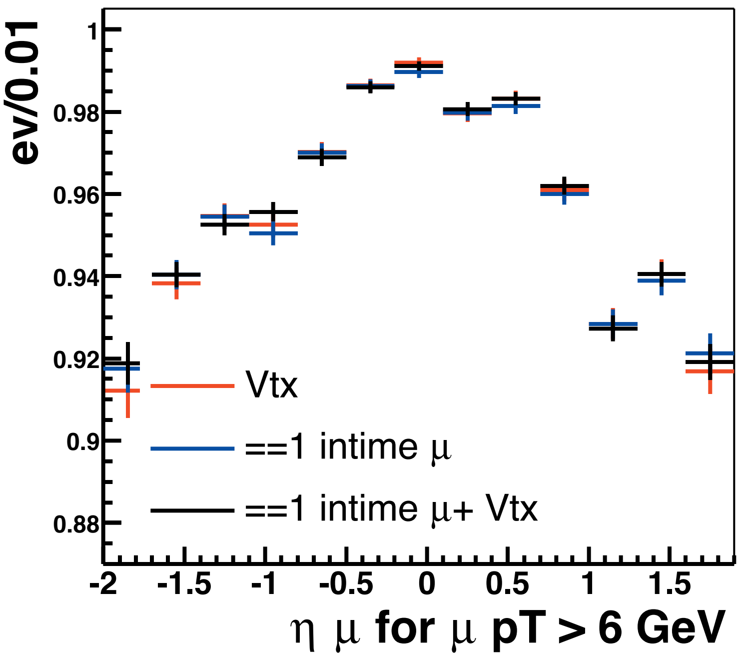


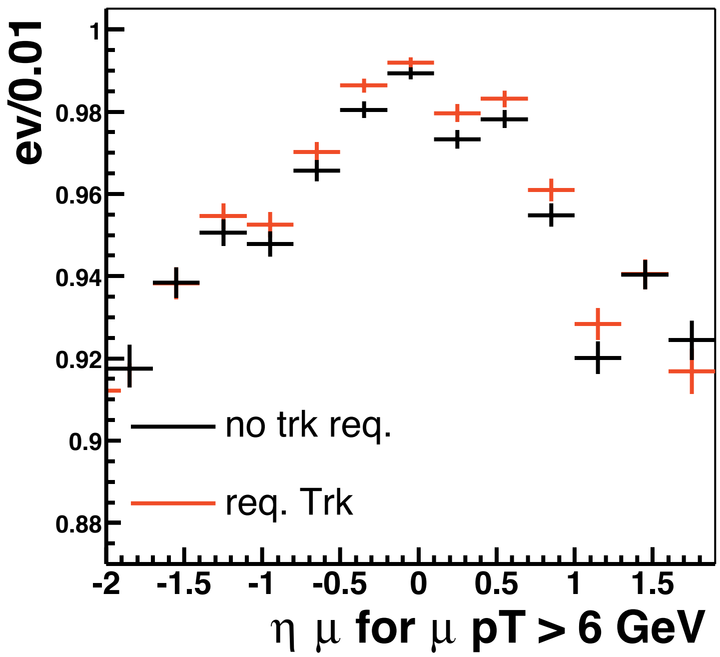


The smearing has most effect on high pT muon which are of less interest for taus. On the other hand the smearing was obtained using Z events, thus I take the full systematic error of the pT smearing as obtained for

Muon L1 trigger - details:

The efficiencies looking at AO-terms have been compared to the L1 terms as cross check. The selection of the used events has been varied to estimate the systematic uncertainly of the efficiency.



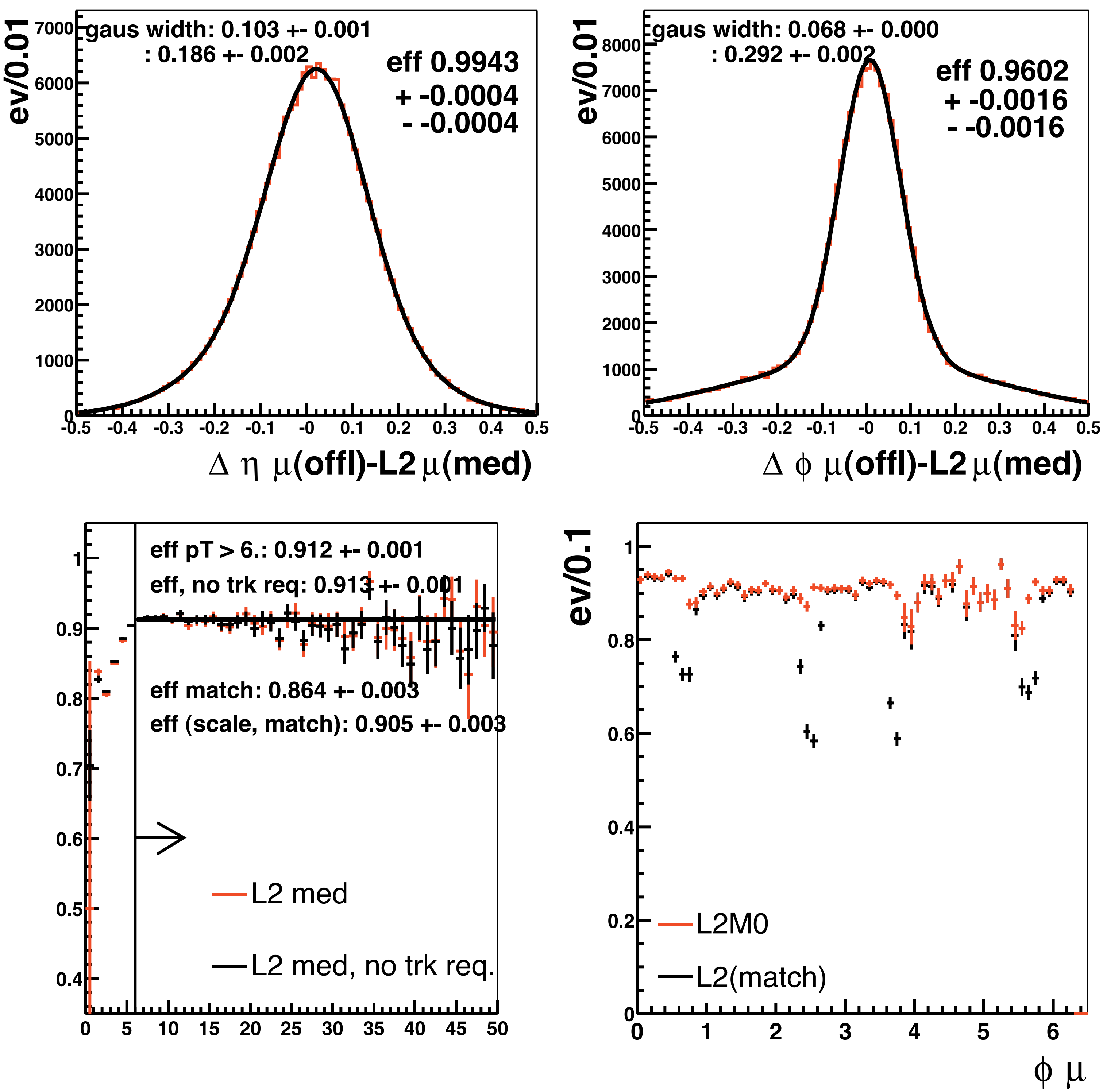


The influence of requiring a good vertex and of the di-muon veto are neglegible. The track requirement results in a slightely higher efficiency which is most likely due to the higher purity of the triggered sample.

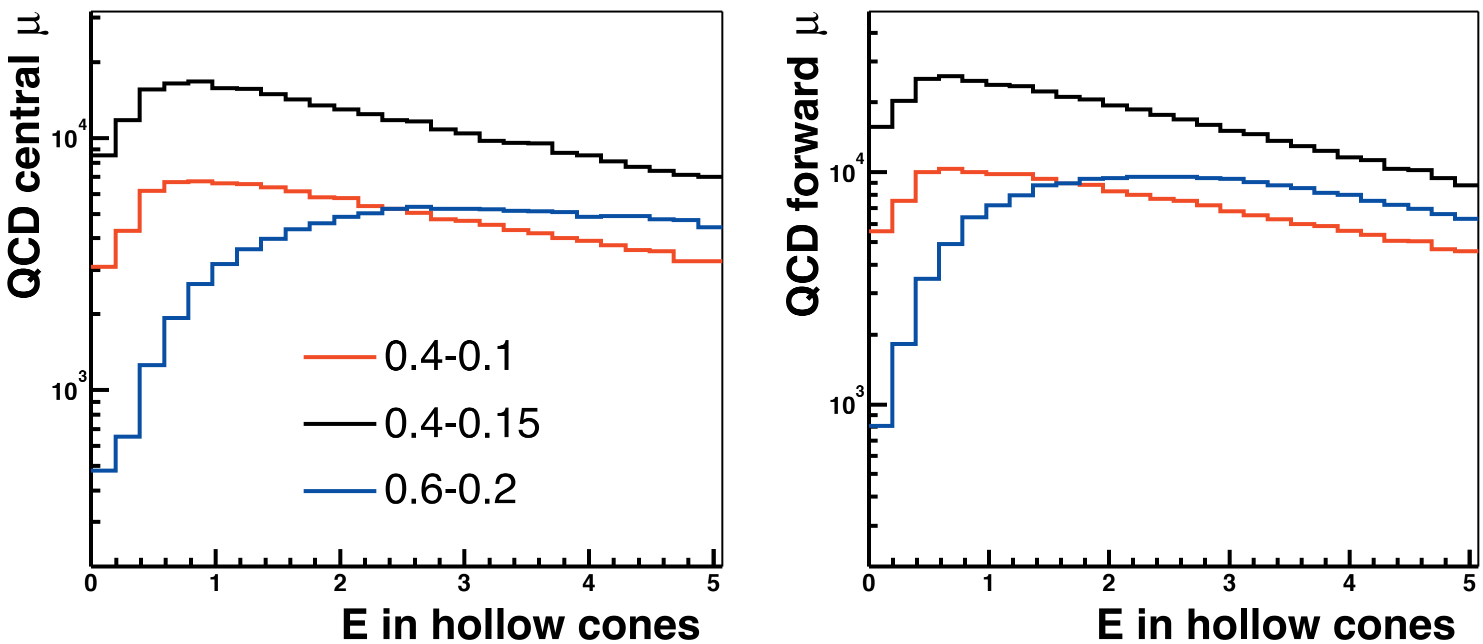
The most significant source of uncertainly are the MC statistics of the signal sample which is needed to fold the efficiency as function of eta with the expected MC distribution.

Muon L2 trigger - details:

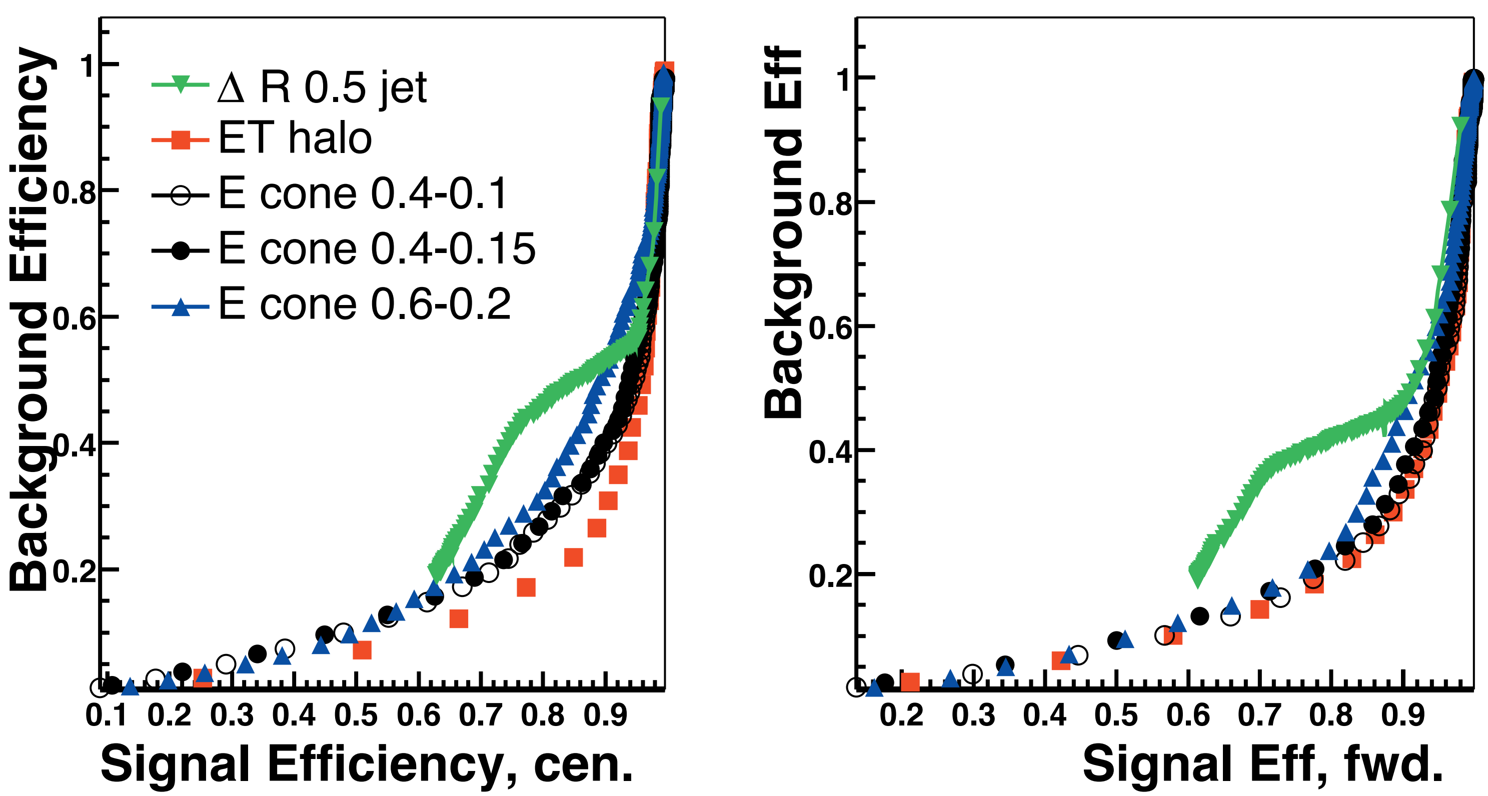
The resolution of the L2 muon angle have been fitted and the efficiency loos due to the cut at a cone of 0.5 has been estimated. This corrected efficiency was compared to the one obtained check the L2 but for >=1 medium quality L2 muon. Both numbers agree resonably well and the difference is quoted as systematic uncertainty.

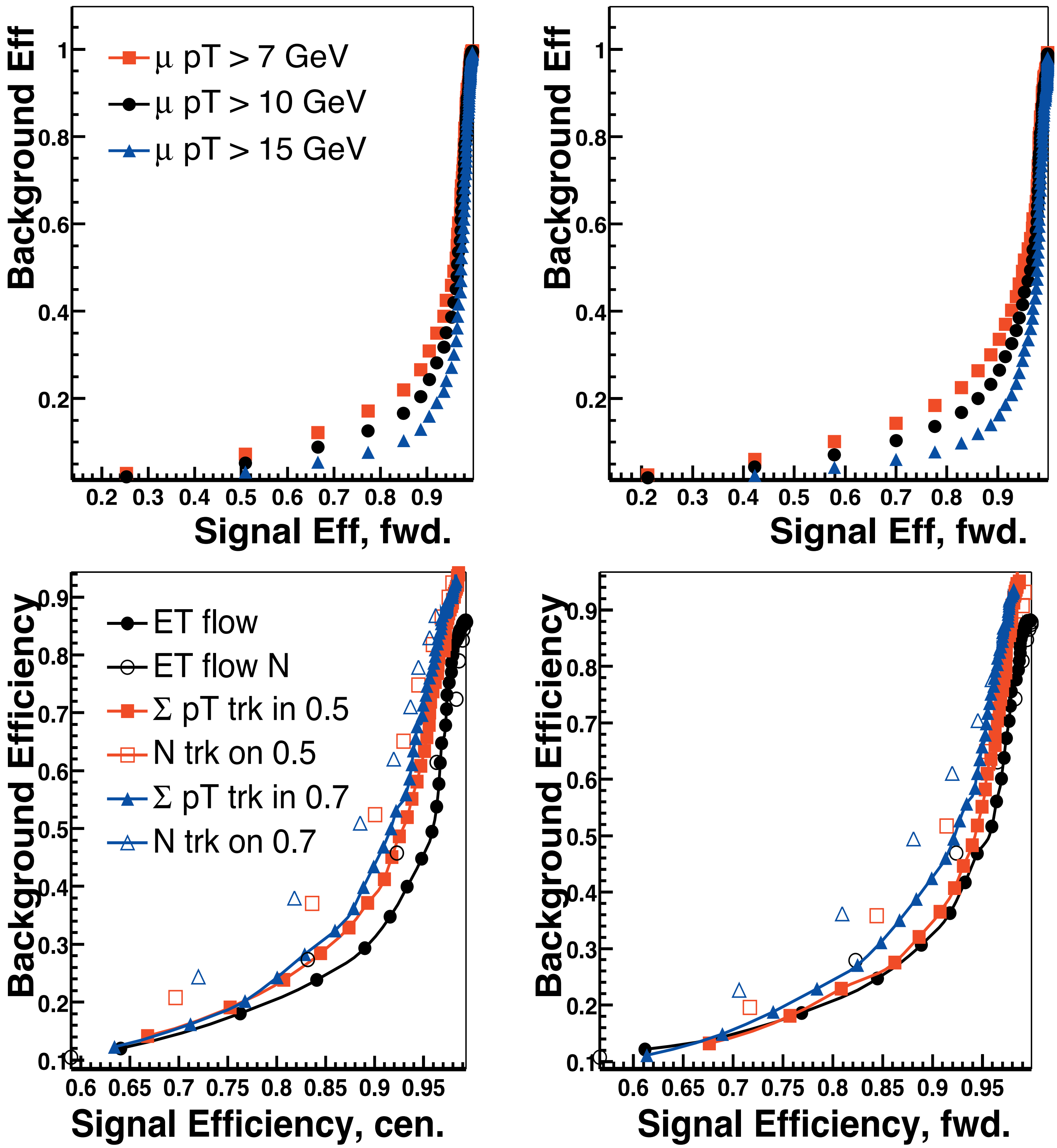


Muon isolation - details:

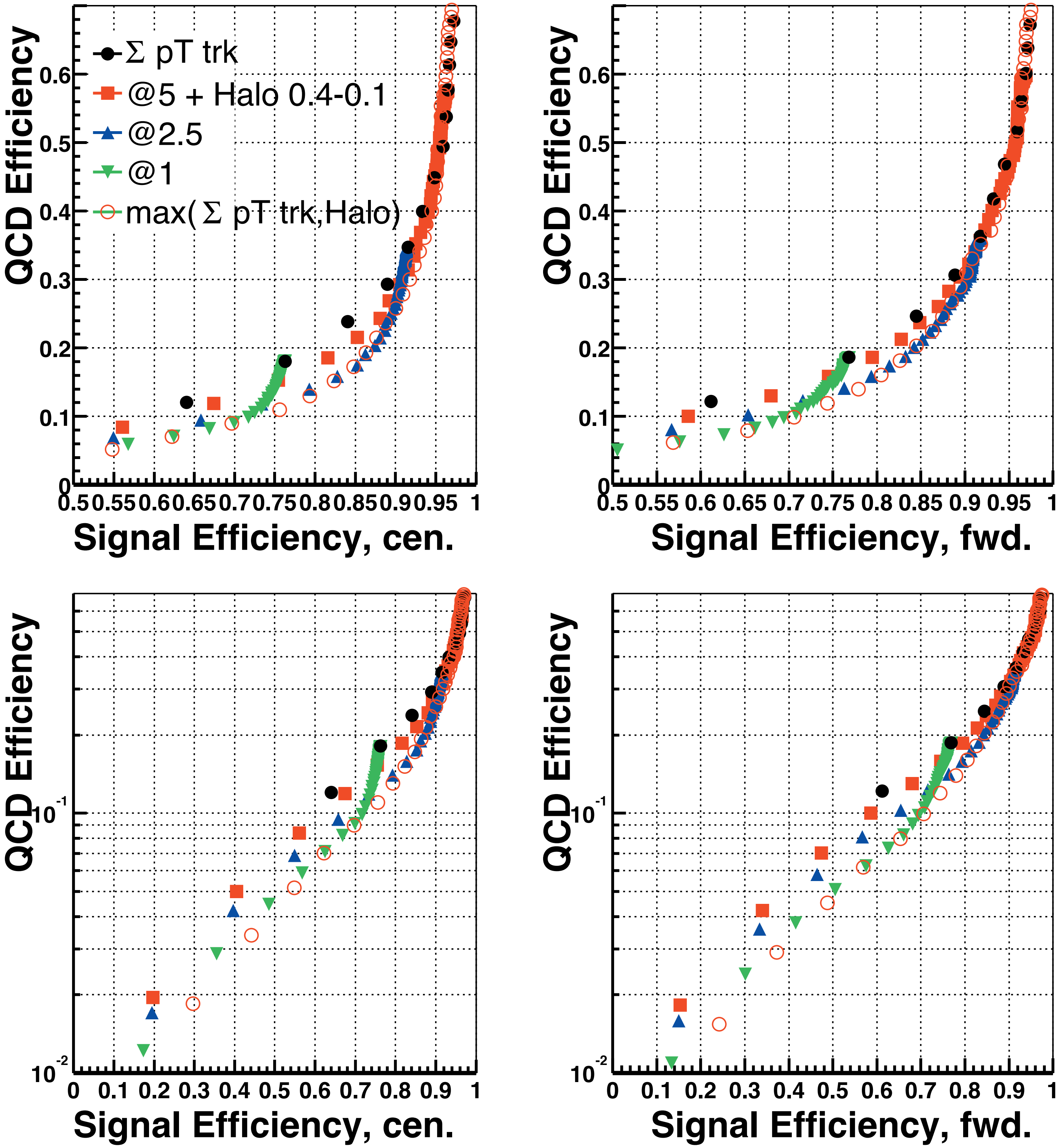


The background sample does not seem to have a significant contribution of signal W/Z -> mu events. Thus the histograms are used directly to plot efficiency versus rejection.





The best result sohould be expected by a combination of variables. All of the isolation variables are strongly correlated so that the most enhancemant of rejection power can be expected by combining track and calorimeter based information. The following plots shows the combination of the best track-based ("et flow") and calorimeter -based variable (et energy between 0.4 and 0.1).



Σ pT trk
@5 + Halo 0.4-0.1
@2.5
@1
max(Σ pT trk,Halo)
QCD Efficiency
Signal Efficiency, cen.
Signal Efficiency, fwd.